REMARKS

The present application was filed on July 25, 2003 with claims 1 through 22. Claims 12 and 21 were cancelled in the Amendment and Response to Office Action dated December 20, 2006. Claims 1-11, 13-20, and 22 are presently pending in the above-identified patent application. Claims 13 and 22 are proposed to be amended herein.

In the Office Action, the Examiner maintained the Restriction Requirement dated March 16, 2007. The Examiner asserts that FIGS. 1-3 should be designated by a legend such as "Prior Art," and rejected claims 13 and 22 under 35 U.S.C. §112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. The Examiner rejected claims 1-8 and 14-17 under 35 U.S.C. §103(a) as being unpatentable over Phanse et al. (United States Patent Number 7,130,366 B2) in view of Walach et al., "The Least Mean Fourth (LMF) Adaptive Algorithm and its Family," IEEE Trans. Communications on Information Theory, vol. IT-30, no. 2, 275-283 (March 1984) and Zerguine, "Convergence Behavior of the Normalized Least Mean Fourth Algorithm," IEEE 2000, rejected claims 1-6 and 14-17 under 35 U.S.C. §103(a) as being unpatentable over Choa et al. (United States Patent Number 6,718,087) in view of Walach et al. and Zerguine, rejected claims 7 and 8 under 35 U.S.C. §103(a) as being unpatentable over Choa et al. and Walach et al. and Zerguine, and further in view of Kaleh (United States Patent Number 5,048,058), and rejected claims 11, 13, 20, and 22 under 35 U.S.C. §103(a) as being unpatentable over Phanse et al. in view of Ramaswami et al., "Optical Network: A Practical Perspective," Second Edition, Morgan Kaufmann, 2002, pp. 258-263.

Election/Restriction

The Examiner maintained the Restriction Requirement dated March 16, 2007. In particular, the Examiner indicates that claims 9-10 and 18-19 are withdrawn from consideration as not directed to the elected species.

Drawings

The Examiner asserts that FIGS. 1-3 should be designated by a legend such as --Prior Art--.

FIGS. 1-3 have been amended to designate the cited figures as prior art

Section 112 Rejections

Claims 13 and 22 were rejected under 35 U.S.C §112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. In particular, the Examiner notes that claims 13 and 22 depend on claims 12 and 21, respectively, and that claims 12 and 21 have been cancelled.

Claims 13 and 22 have been amended to depend on claims 11 and 20, respectively.

Independent Claims 1 and 14

Independent claims 1 and 14 were rejected under 35 U.S.C §103(a) as being unpatentable over Phanse et al. in view of Walach et al. and Zerguine, and under 35 U.S.C. §103(a) as being unpatentable over Choa et al. in view of Walach et al. and Zerguine. Regarding claims 1 and 14, the Examiner acknowledges that Chao fails to teach a least-mean 2Nth-order (LMN) algorithm, where N is greater than one, but asserts that Walach discloses a least-mean $2N^{th}$-order (LMN) algorithm, where N is greater than 1, and that Zerguine teaches that NLMF gives a smaller error (FIG. 3) or faster convergence (FIG. 4). The Examiner also asserts that the difference between Phanse et al. and the claimed invention is that Phanse teaches LMS while the claimed invention claims least-mean $2N^{th}$-order algorithm with N greater than one.

Applicants note that, in electronic communication systems such as wireless or wireline links, the accumulated noise *n(t)* along an electronic channel is usually additive Gaussian noise. Therefore, by denoting the electronic signal as *x(t)*, the received signal *y(t)* becomes y(t)=x(t)+n(t) without any channel distortion. (For a detailed description of the Gaussian approximation see, for example, Marcuse, Dietrich, "Calculation of Bit-Error Probability for a Lightwave System with Optical Amplifiers and Post-Detection Gaussian Noise," Journal of Lightwave Technology, Vol. 9, No. 4, April 1991.) As a result, the LMS algorithm should be applied. For example, Walach teaches that,

> for instance if n_j is Gaussian then $\alpha(2)=(9/15)<1$ Therefore in that particular case, *LMS will outperform LMF*."
> (Page 280, last sentence; emphasis added.)

Thus, Walach advises to use only LMS (instead of LMF or LMN). In fact, no disclosure or suggestion could be found in the cited prior art to utilize LMF or LMN for a system with an additive Gaussian noise.

In optical communication systems using direct detection, however, the received signal *u(t)* is proportional to the photocurrent *I(t)* induced in the photo-detector which is proportional to $P_N(t)$. The power of the noise-coupled optical signal $E(t) + n_0(t)$ (without considering the effect of distortion or any optical and electronic filters along the signal path) is:

$$u(t) \propto I(t) \propto P_N(t) = \left|x(t) + n(t)\right|^2 = |x(t)|^2 + 2\Re\{x(t)n^*(t)\} + \left|n(t)\right|^2 \qquad (1)$$

This is the direct result of square-law photo detection which only converts optical energy (instead of optical field) into electronic current. **Therefore, the noise is not a simple addition to the signal, but is "convolved with the signal and itself in the frequency domain" through the cited squaring operation, significantly changing the noise characteristic of the received signal *u(t)*.** In fact, the noisy input signal *u(t)* contains a signal-dependent non-symmetric Gaussian second term having a variance determined by the signal levels of bits 0/1, and a nonzero-mean noncentral χ^2 third term. This squaring effect is typically ignored and it is commonly assumed that the noise term is accounted for "additively" and distributed Normally as a Gaussian distribution. This assumption has conventionally led to the use of LMS in optical communication systems as the optimal algorithm to adapt the filter coefficients. This assumption is a valid approximation *only when the noise is very small and the third term can be ignored,* and when the *signal-dependent second term can be approximated by a simple Gaussian random variable.* However, when the accumulated optical noise along the optical path becomes large (for example in a long-haul system having an optical path of a length longer than 1000 km), *this third term becomes significant* and affects the performance of an equalizer employing the LMS algorithm. Thus, based on an analysis of the noise characteristic in a noisy environment, the present invention recognizes that the assumption based on additive Gaussian noise (as cited above) is no longer valid and, therefore, *LMS is no longer suitable for optical communications.*

Based on this new finding, the present invention also recognizes that LMF/LMN performs better than the commonly used LMS in optical communications

Similarly, Zerguine teaches the advantage of using NLMF in a non-Gaussian noise environment with an additive zero-mean uniformly-distributed noise w_n, which is similar to the noise depicted in Fig. 3 (b) of Walach. Therefore, both Walach and Zerguine are directed to the same kind of uniformly-distributed noise which is very different from the noise encountered in an optical communication system. Neither Walach nor Zerguine has considered the squaring effect of the summation of the signal and the noise, and neither Walach nor Zerguine disclose or suggest *utilizing LMF in an optical communication system*.

In addition, Applicants can find no disclosure or suggestion in Walach, Zerguine or Phanse to combine the techniques of Phanse with the invention of Walach or Zerguine, and can find no disclosure or suggestion in Walach, Zerguine or Choa to combine the techniques of Choa with the invention of Walach or Zerguine. Contrary to the Examiner's assertion, *none of the cited references considered using the LMN algorithm on an optical channel*. Independent claims 1 and 14 require removing intersymbol interference from said electrical signal using an equalizer, wherein said equalizer has a plurality of coefficients; and updating said plurality of coefficients based upon a least-mean $2N^{th}$-order (LMN) algorithm where N is greater than one.

Thus, Phanse et al., Walach et al., Zerguine, and Choa et al., alone or in combination, do not disclose or suggest_removing intersymbol interference from said electrical signal using an equalizer, wherein said equalizer has a plurality of coefficients; and updating said plurality of coefficients based upon a least-mean $2N^{th}$-order (LMN) algorithm where N is greater than one, as required by independent claims 1 and 14.

Independent Claims 11 and 20

Independent claims 11 and 20 were rejected under 35 U.S.C. §103(a) as being unpatentable over Phanse et al. in view of Ramaswami et al. Regarding claims 11 and 20, the Examiner acknowledges that Phanse does not teach to adjust the threshold based on signal distribution, but asserts that it is well known in communication theory that a decision threshold should be chosen based on probability density functions of the "0" and "1" of the data stream

(see, Ramaswami et al.).

Independent claims 11 and 20 have previously been amended to incorporate the features of claims 12 and 21, respectively. In previously rejecting claims 12 and 21, the Examiner asserted that Phanse teaches a threshold control algorithm to track said signal distribution of said electrical signal and adjust said slicing threshold for a reduced bit error rate of said predicted signal (FIG. 6B: Threshold values 212; paragraph 0243). As the Examiner noted, Phanse teaches to determine the slicer threshold values 212 in paragraph 0243 and FIG. 6B; *Phanse uses the contents of a shift register 214 to determine the slicer threshold value 212 The shift register 214 receives the sliced data 211 as the input*

Applicants also note that Ramaswami assumes an additive signal-dependent Gaussian noise (see, for example, equation 14.3) and does *not* consider *the squaring effect of the summation of the signal and the noise* to reflect the complete picture of the "convolved" noise effect. Secondly, Applicants note that Ramaswami only uses the Q factor to theoretically calculate the minimum possible bit error rate. In one aspect of the present invention, *the slicing threshold is adaptively adjusted to obtain a reduced bit error rate.*

Thus, as argued above, Ramaswami does not address the third term of equation (1) above In addition, while Ramaswami is useful *for simulations and theoretical analysis*, a person of ordinary skill in the art would *not* be motivated to combine Phanse and Ramaswami in the implementation of a system to ***track a signal distribution of an electrical signal*** *and* ***adjust a slicing threshold*** *for a reduced bit error rate of a predicted signal.* Independent claims 11 and 20 require a slicer to produce a predicted signal in response to each input signal based upon a slicing threshold, wherein said slicing threshold is varied based upon a signal distribution of said electrical signal; and a *threshold control algorithm to* ***track said signal distribution of said electrical signal*** *and* ***adjust said slicing threshold*** *for a reduced bit error rate of said predicted signal* Phanse does not disclose or suggest ***tracking the signal distribution of the electrical signal*** *and* ***adjusting the slicing threshold*** *for a reduced bit error rate of said predicted signal.*

Thus, Phanse et al. and Ramaswami et al., alone or in combination, do not disclose or suggest a slicer to produce a predicted signal in response to each input signal based

upon a slicing threshold, wherein said slicing threshold is varied based upon a signal distribution of said electrical signal; and a threshold control algorithm to track said signal distribution of said electrical signal and adjust said slicing threshold for a reduced bit error rate of said predicted signal, as required by independent claims 11 and 20

Dependent Claims 2-10, 13, 15-19 and 22

Dependent claims 2-8 and 15-17 were rejected under 35 U.S.C. §103(a) as being unpatentable over Phanse et al. in view of Walach et al. and Zerguine, claims 2-6 and 15-17 were rejected under 35 U.S.C. §103(a) as being unpatentable over Choa et al. in view of Walach et al. and Zerguine, claims 7 and 8 were rejected under 35 U.S.C. §103(a) as being unpatentable over Choa et al. and Walach et al. and Zerguine, and further in view of Kaleh, and claims 13 and 22 were rejected under 35 U.S.C. §103(a) as being unpatentable over Phanse et al. in view of Ramaswami et al.

Claims 2-10, 13, 15-19, and 22 are dependent on claims 1, 11, 14, and 20, respectively, and are therefore patentably distinguished over Phanse et al., Choa et al., Walach et al., Zerguine, Kaleh, and Ramaswami et al., because of their dependency from independent claims 1, 11, 14, and 20 for the reasons set forth above, as well as other elements these claims add in combination to their base claim

All of the pending claims, i.e., claims 1-11, 13-20, and 22, are in condition for allowance and such favorable action is earnestly solicited.

If any outstanding issues remain, or if the Examiner has any further suggestions for expediting allowance of this application, the Examiner is invited to contact the undersigned at the telephone number indicated below

The Examiner's attention to this matter is appreciated.

Respectfully submitted,

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